LUCIOL INSTRUMENTS

Application Note LOR-200-01 June 2009

Testing Passive Optical Networks (PON) With the LOR-200

Introduction

There are several applications where the LOR-200 family of high-resolution and high-sensitivity photon-counting OTDR can outperform conventional OTDRs. All conditions, where a high spatial resolution measurement on low backscattered signals is required are typical fields of application. One example are passive optical networks. Here, the fiber spans are relatively short, and due the 1x8 or 1x32 distribution couplers the losses are high. Also, a high spatial resolution is required to resolve closely spaced reflective events, e.g. if optical network terminals need to be localized precisely.

In this example session, we show a typical measurement on a PON using the LOR-200 and compare some results with the traces recorded using a conventional OTDR.

Characteristics of the LOR-200

The most important technical parameters of an OTDR are the dynamic range, the spatial resolution and the dead-zones. The dynamic range is the difference between the highest Rayleigh backscatter level and the instrument's noise level. It reflects the instrument's maximum capability of total fiber loss measurement. The photon-counting technique of the LOR-200 makes high sensitivity optical detection (down to -100 dBm) possible while keeping the detection bandwidth above 2 GHz. That is why the LOR-200 achieves a high dynamic range even with short optical pulses.

A measurement of the LOR-200's dynamic range for different optical pulse-widths is shown in

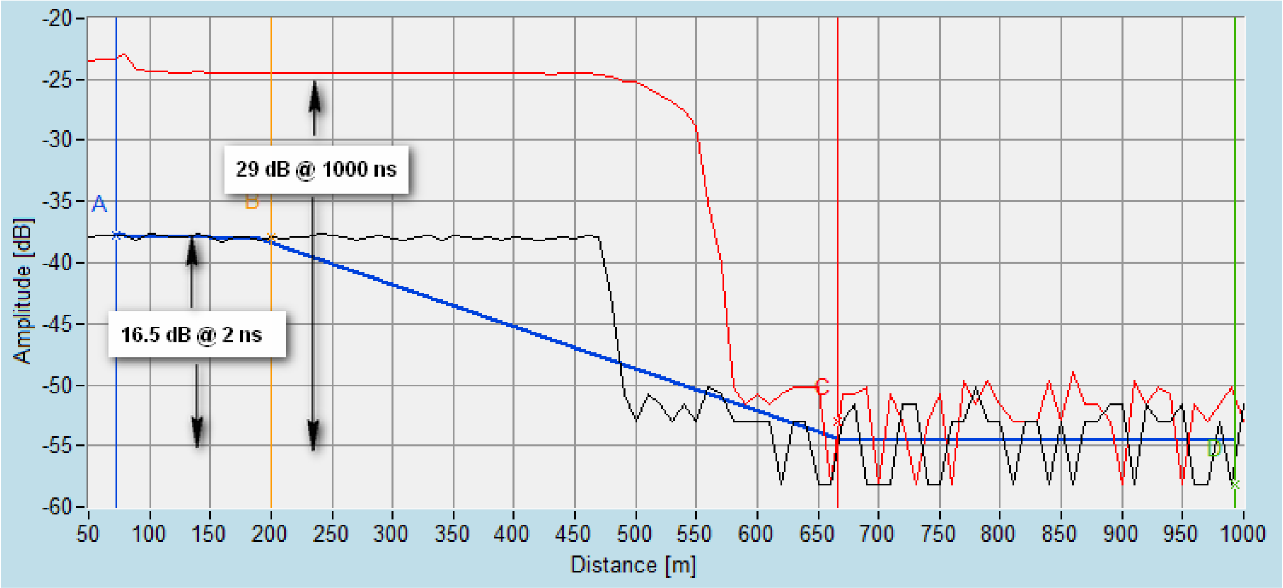


Figure 1: The dynamic range at 2 ns and 1000 ns

From the trace we find a dynamic range of 29 dB for a pulse-width of 1000 ns and 16.5 dB for a pulse-width of 2 ns.

The high detection bandwidth is even more important to achieve high resolution and short dead-zones. The event dead zone indicates the minimum distance of two closely spaced events that can be separately resolved by the instrument. It is generally defined as the distance between one point on the rising edge of the peak, 1.5 dB below the maximum value, and the corresponding point on the falling edge (see Figure 2). The attenuation dead-zone indicates the minimum distance required after a reflective event to perform a loss measurement. It is defined as the distance between the rising edge of the peak and the position on the falling edge of the peak with an amplitude 0.5 dB above the Rayleigh backscatter level. Figure 2 shows a measurement of both dead-zones generated by the reflection of a typical FC/PC connector (ORL= 53 dB) after 1.4 km of optical fiber.

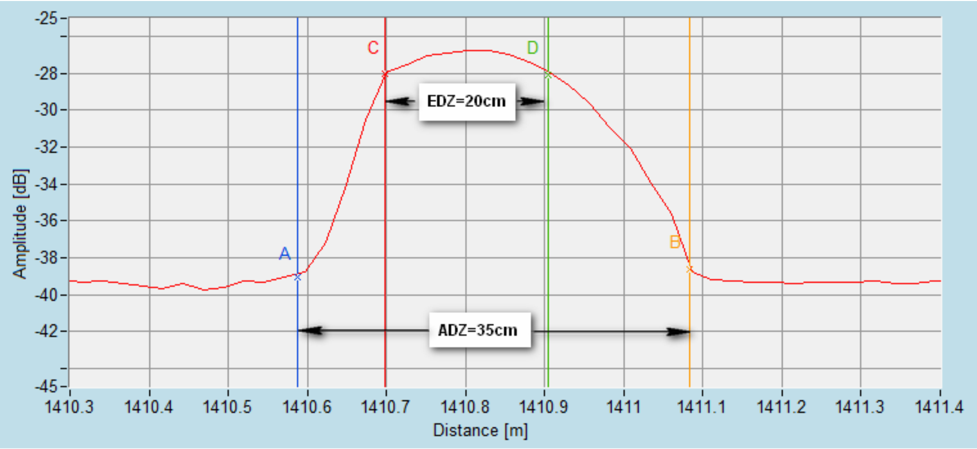


Figure 2: The dead-zones of the LOR-200. ORL = 53 dB.

The short event dead-zone of only 20 cm and the attenuation dead-zone of only 30 cm allow a precise location of faults, losses and reflective events. A more detailed example measurement session can be found in the following section.

Even at longer optical pulse-widths the LOR-200 outperforms conventional OTDRs. The high detection bandwidth ensures an almost rectangular shape of the detected reflective events. A comparison to a conventional OTDR can be found in Figure 3.

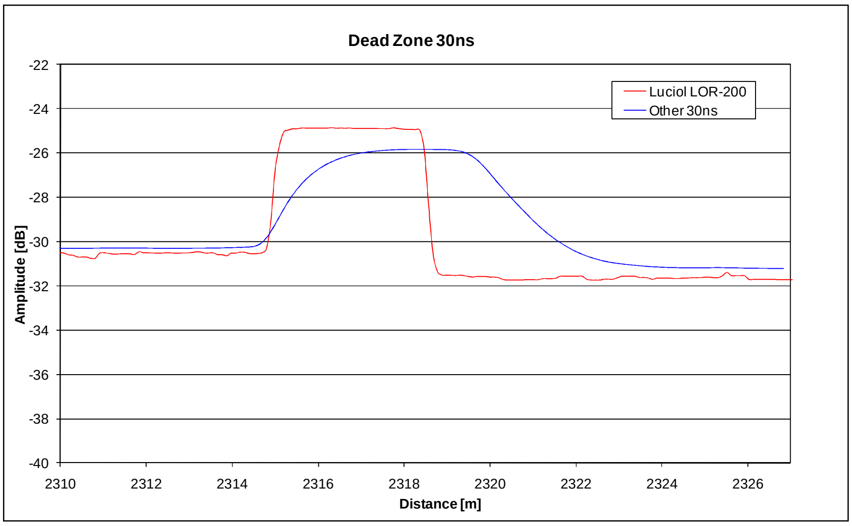


Figure 3: Comparison of dead zones at 30 ns pulse-width

Even so the pulse-width is 30 ns for both instruments; the LOR-200 achieves half the attenuation dead-zone of the conventional OTDR.

Testing a passive optical network

Passive optical networks provide in a point to multipoint configuration high bandwidth to the end user. A typical architecture is outlined in Figure 4.

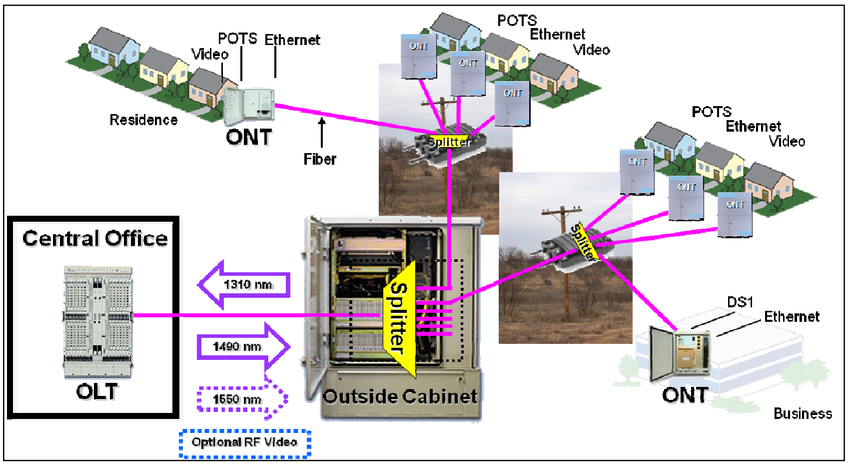


Figure 4: FTTx/PON Neighborhood Architecture

The LOR-200 offers several advantages when testing and monitoring PON. PON have high losses due to splitters on relatively short fiber lengths this i.e. a high dynamic range at short pulse widths is needed. Due to the multitude of couplers and parallel fibers, there are a large number of closely spaced reflective and non-reflective events. This requires an OTDR with high resolution and high sensitivity to measure from the OLT to ONT (point to multi-point).

In this section the LOR-200 is used to test a simplified passive optical network as illustrated in Figure 5.

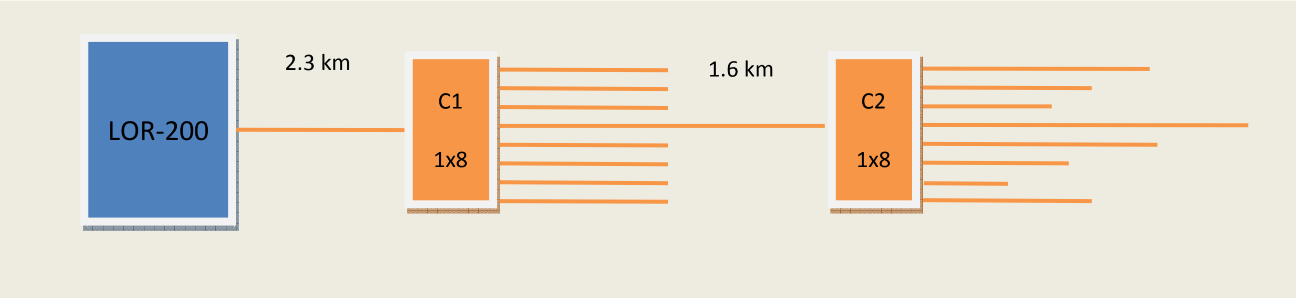
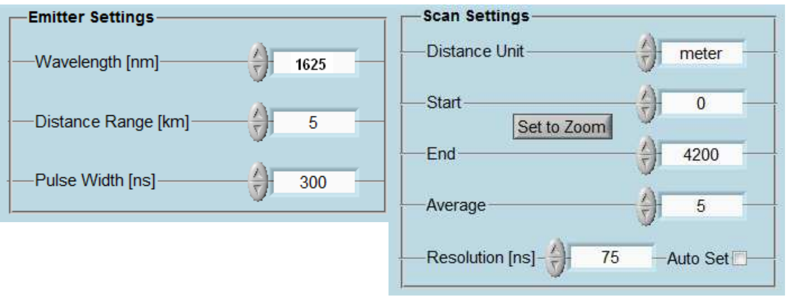


Figure 5: The fiber network under test.

The OTDR is connected to a 2.3 km long fiber spool followed by a 1x8 optical coupler (C1). One output fiber of the coupler is connected to a second 1.6 km long fiber spool followed by a 1x8 coupler (C2). The 8 output fibers of the second coupler are cut to different lengths. The total one-way loss of the system is 24 dB for each of the 8 output fibers. Assuming Fresnel reflections at the fiber ends (ONT locations with ORL≈15 dB); the back-reflected signal from each end is 63 dB lower than the input signal.

To get an overview of the network the LOR-200 is first started with the settings as shown on the right. The pulse-width is set to 300 ns and the *Start* and *End* positions cover the entire PON. The resulting trace is shown in Figure 6.



Emitter Settings

Wavelength [nm] 1625

Distance Range [km] 5

Pulse Width [ns] 300

Scan Settings

Distance Unit meter

Start 0

End 4200

Average 5

Resolution [ns] 75

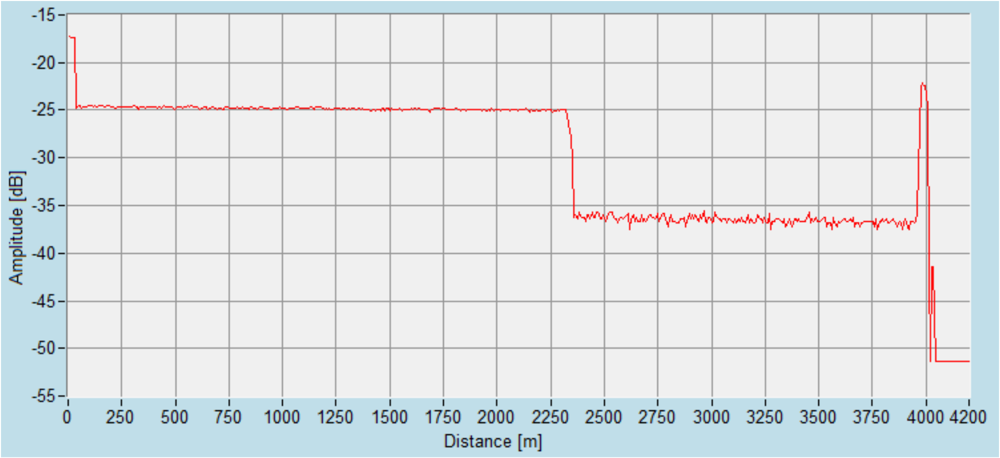


Figure 6: LOR-200 trace of the entire network.

Obviously, the resolution is not sufficient to resolve the different lengths of the fibers leaving the second coupler C2. As discussed in the previous sections, the LOR-200 is capable of working with a much higher resolution. For the second measurement the pulse-width is reduced to 2 ns and the resolution is now 500 ps. The scan range is set to a 10 meter window centered to the 8 reflections. The result is shown in Figure 7.

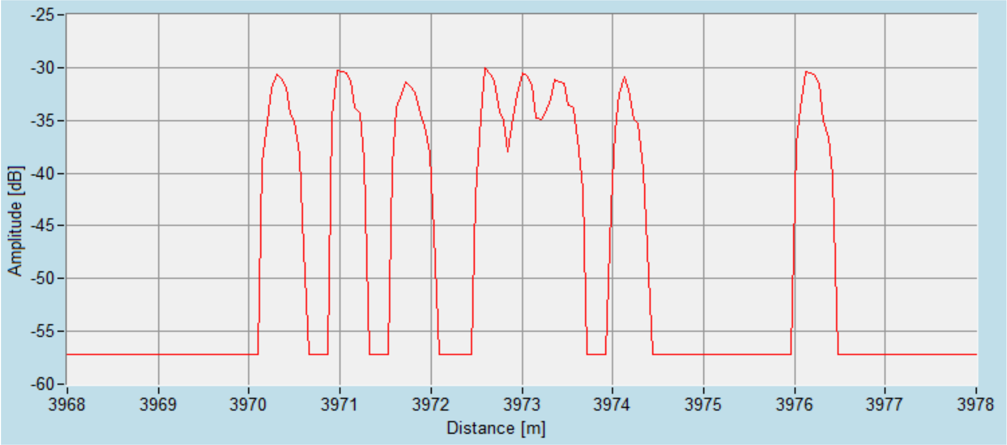


Figure 7: PON trace - Zoom to the ONT locations

The high spatial resolution and the minimal dead-zone of the instrument make all 8 reflective events visible. Adjacent reflections spaced by only 20 cm can be resolved.

The LOR-200 software contains several tools to let the user carry out typical measurements. Manual and automatic analysis tools are provided. An example of a manual insertion loss measurement at the coupler C1 is shown in Figure 8.

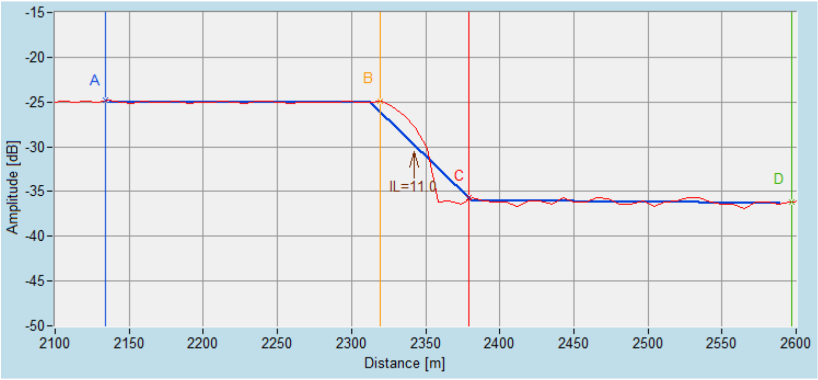


Figure 8: Insertion loss measurement at C1.

Select *Event Loss* form the measurement menu and simply set 2 cursors before and 2 cursors after the event. The application will do all the fitting and calculation of the insertion loss. The value can be added to an event table. In this example we find an insertion loss of 11 dB. The fiber loss can be found in a similar way using the *Fiber Loss LMS* tool.

The *Manual Peak* tool is used to find peak amplitudes and the optical return loss. Figure 9 is another example of the simplified PON now with varying reflectance values at the ONT locations. The y-scale of the trace window is automatically changed to correspond to the reflected optical power. Note that the indicated amplitudes on the trace are relative values compared to the emitted optical output power. In the presence of losses, the accumulated loss before the reflective event needs to be taken into account for local return loss calculations. All data for the analyzed events can be added to the event table.

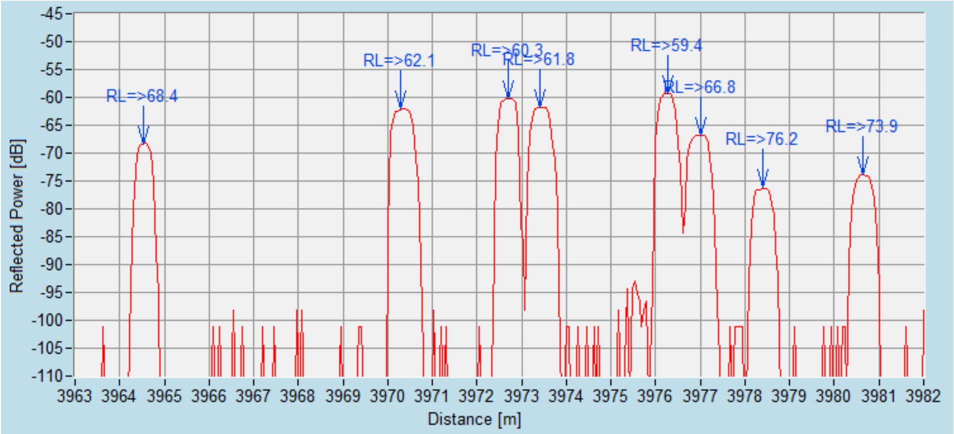


Figure 9: Reflectance measurement at the ONT locations

Comparing Traces and Fault Location

The LOR-200 allows comparing the measured data with up to two previously saved reference traces. Comparing traces is very useful for troubleshooting and fault location. Some examples are given in this section.

First we analyze and localize an event creating fiber losses. The red trace serves as the reference data it was recorded with a PON configuration like in Figure 5.

The measured data shown in the black trace reveals an additional loss close to the coupler C1.

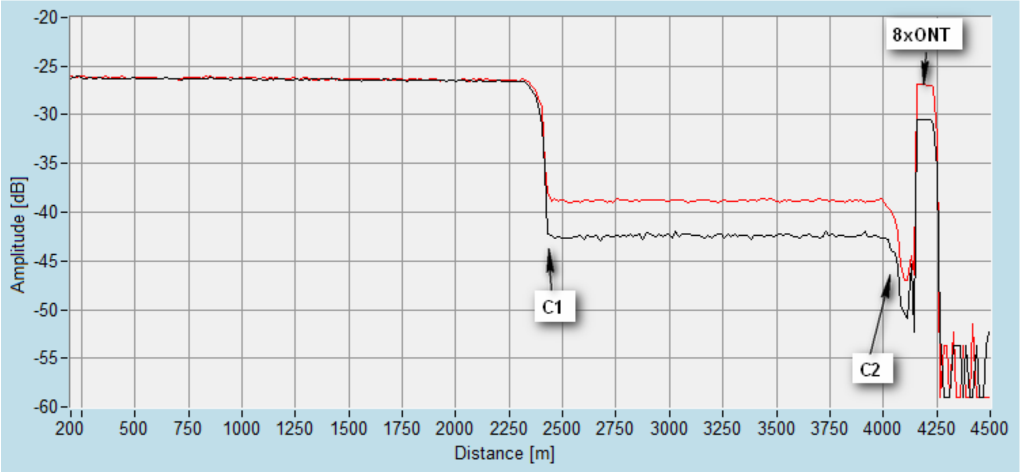


Figure 10: PON troubleshooting - Bend loss close to C1

The high resolution of the LOR-200 allows a precise location and analysis of this event. A second trace is recorded with a higher resolution (5ns pulse-width) centered on the area where the fault is located. The result can be found in Figure 11.

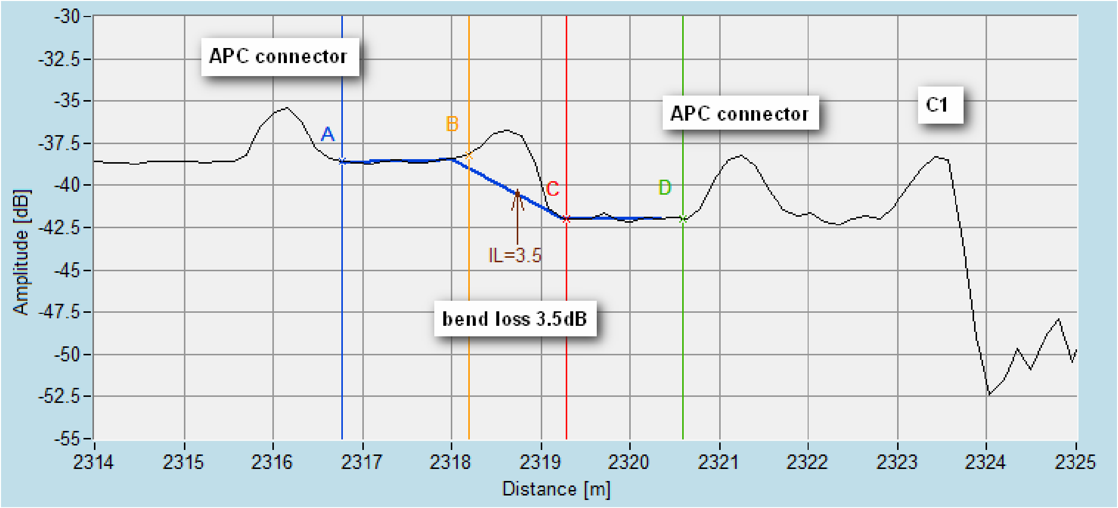


Figure 11: PON troubleshooting – High resolution analysis of a bend loss

Now much more details are visible. Two low-loss APC connectors are detected and the bend-loss is precisely localized about 5 m in front of C1.

In the next example we look at the reflections created by the network terminals (ONT). The red trace in Figure 12 serves again the reference trace. The green trace shows all reflections attenuated by 3.5 dB. This corresponds to the case in the first example indicating an event creating losses before C2.

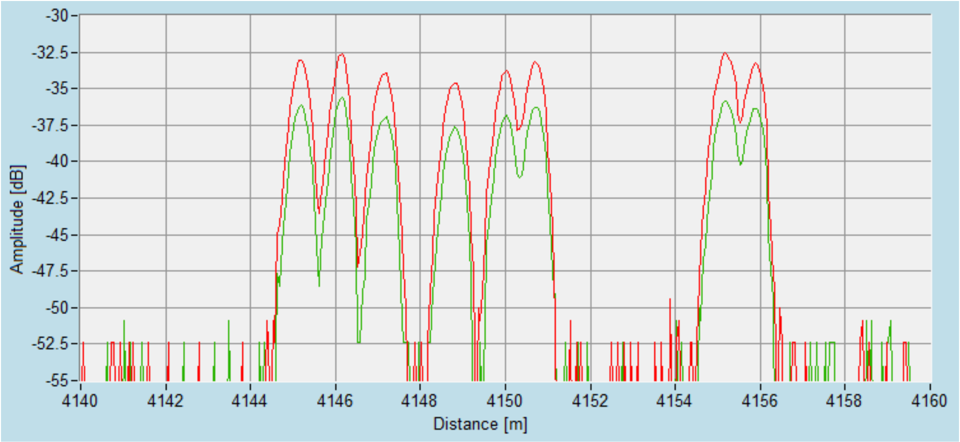


Figure 12: PON troubleshooting – Zoom to the ONTs.

A fault in the network can be detected as shown above by comparing the trace at the ONTs with a reference trace. Further examples are depicted in Figure 13 and Figure 14.

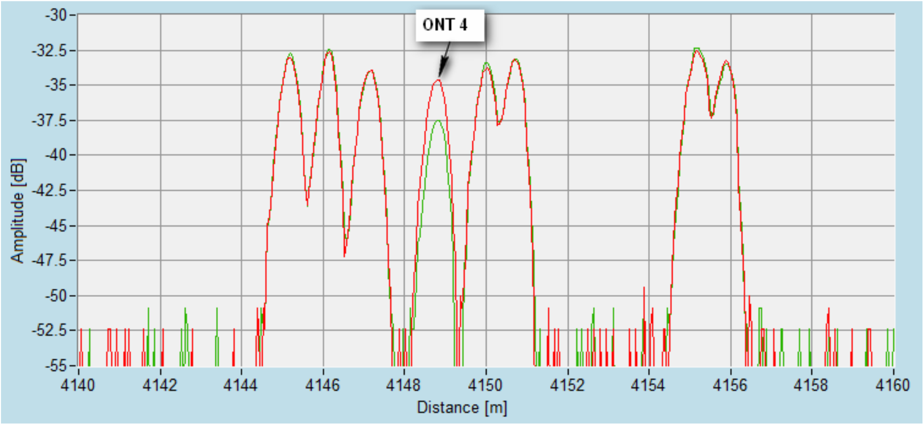


Figure 13: PON troubleshooting – Loss in the fiber connected to ONT 4.

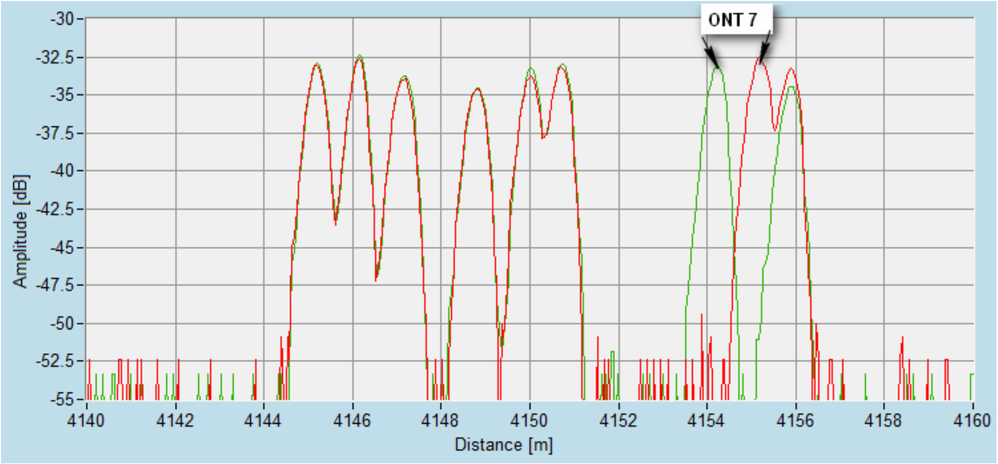


Figure 14: PON troubleshooting – Fiber connected to ONT 7 broken.

In the first case (Figure 13) additional losses in the fiber leading to ONT 4 reduce the amplitude of the corresponding reflection.
In the second case (Figure 14) the fiber connected to ONT 7 is broken. The corresponding peak has disappeared and a new peak caused by the fiber break appears about 1m before the terminal.

There are many other fault conditions where the LOR-200 allows locating and characterizing very precisely all kinds of defects in passive optical networks. Contact Luciol Instruments for further information.